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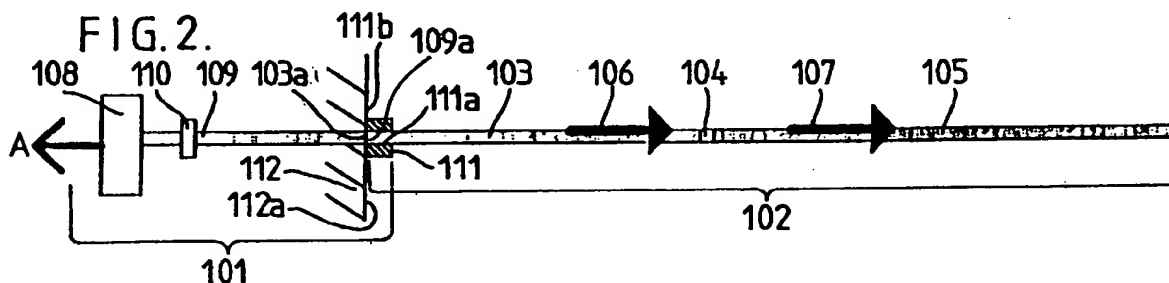
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### (54) Split Hopkinson bar testing apparatus

(57) FIGURE 2 shows compression wave generation apparatus 101 to the left of split Hopkinson pressure bar 102 including input bar 103 connected via test specimen 104 to output bar 105. Compression wave 106, 107 is generated by initially placing impactor bar 109 under a pre-load force by hydraulic actuator 108 (in

the direction of arrow A) until fragile component 110 ruptures causing end 109a to impact input end 103a of the input bar 103. End 109a is guided and held adjacent end 103a by collar 111 welded to end 109a prevented from movement to the left by blocking system 112.



## Description

This invention relates to improvements in or relating to specimen testing apparatus such as that known as Hopkinson bar testing apparatus.

The use of a pressure bar such as a Hopkinson bar is well known to obtain information regarding, for example, the dynamic mechanical properties of a specimen of material placed in compression. In particular, a split Hopkinson pressure bar (SHPB) has been utilised for different case studies on the dynamic mechanical behaviour of materials. Where a study of a specimen of the material in compression is required, Using a split Hopkinson pressure bar, conventionally, a compression wave is generated in the input bar by means of a cylindrical projectile fired from a gas gun to impact one end of the input bar, the other end of the input bar being connected by the specimen under test to the output bar from which information can be gathered by sensors in a well known way. However, it is believed that, at least in some circumstances, the generation of a compression wave, by firing a projectile onto the input end of the impact bar, tends to be disadvantageous more particularly in avoiding imperfect energy transfer at the interface of the forward end of the projectile coming into contact with the input end of the input bar. Theoretically, the projectile and bar should be perfectly parallel at the moment of impact with particular attention being given to guidance of the projectile inside the delivery gas gun. Additionally, the contact surfaces of the projectile and input bar at the interface need to be mechanically treated in order to preserve substantial contact between the entire front surface of the projectile and the input surface of the input bar at the moment of impact. Thus, in practice, in order to avoid energy transfer problems that can occur at the interface between the projectile and the input bar, a certain criticality of construction is required that does not allow much room for tolerance. Additionally, where a specimen of material is of increased diameter or size there will be a need to increase the diameter of the projectile with consequent modifications being needed to the gas gun to deliver such a projectile or replacement of the gun by a larger one.

It is an object of the present invention to provide apparatus for generating a compression wave or pulse in an input bar or member of a Hopkinson or pressure bar system, which apparatus at least alleviates one or more of the aforementioned, or other, problems associated with compression wave generation apparatus. According to the present invention there is provided compression wave or pulse generation apparatus capable of generating a compression wave or pulse in an input bar or member of a pressure bar system such as a split Hopkinson pressure bar, said compression wave generation apparatus comprising an impactor bar or member held, in use, adjacent one end of the input bar or member and supported to resist movement in a direc-

tion away from said input bar/member when the impactor bar/member is pre-loaded in said direction by actuator means, the arrangement being such that, in use, the pre-load force can be quelled suddenly e.g. by rupture of a fragile or frangible component in the impactor bar/member, so that the impactor bar/member is released into impact or energy transfer with the input bar/member thereby transmitting a compression wave or pulse through the input bar to a specimen under test.

The actuator means may be any convenient means such as a hydraulic or pneumatic actuator.

Where a fragile or frangible component is provided in an impactor bar/member as aforementioned, said member is, preferably, arranged to rupture at a particular pre-set value of the preload force provided by the actuator means.

In one embodiment of the present invention, the impactor bar/member is guided and held adjacent an input end of the input bar/member (and remains adjacent the input bar during application of the preload force), preferably by means of a collar connected to one end of said impactor bar/member. In use, the collar receives the input end of the input bar and holds same adjacent the impact end of the impactor bar/member; said collar may be welded to the end of the impactor bar/member and/or may be cylindrical. Preferably, the internal diameter or dimension of the collar closely matches the external diameter or dimension of the input bar which in turn matches the diameter or dimension of the impactor bar. A blocking system or fixed support may be provided at the rear of the collar surrounding the impactor bar/member thereby resisting or preventing movement of the impactor bar in said direction on the application of the preload force. Thus, no preload force is exerted on the input bar in said direction when said preload force is applied to the impactor bar/member.

Usually, the input bar will be connected to an output bar via the specimen to be placed under a compression test.

Further according to the present invention there is provided a method of inducing or generating a compression wave or pulse in an input bar or member of a pressure bar system such as split Hopkinson pressure bar, said method comprising pre-loading an impactor bar or member in a direction away from said input bar and suddenly removing the preload force (for example by rupturing a fragile or frangible component of the impactor bar/member) thereby releasing the impactor bar/member into impact or energy transfer with the impactor bar/member thus transmitting a compression wave through the input bar to a specimen under test.

Further advantageous apparatus and method features of the present invention will be apparent from the following description and drawings.

An embodiment of compression wave generation apparatus for generating a compression wave in a split Hopkinson bar will now be described, by way of example only, with reference to the accompanying very much

simplified diagrammatic drawings in which:

FIGURE 1 shows a longitudinal view of prior art compression wave generation apparatus and split Hopkinson pressure bar, and

FIGURE 2 shows a compression wave generation apparatus and a split Hopkinson pressure bar in accordance with the present invention.

FIGURE 1 of the drawings shows schematically a known arrangement for generating a compression wave in a split Hopkinson pressure bar 1, comprising an input bar or member 2 connected via a specimen under test 3 to an output bar or member 4. A gas gun 5 is arranged to fire a suitable projectile 6 into impact with the free end 2a of the input bar 2 in a manner which should be self-evident from FIGURE 1. Thus, the projectile generates a compression wave in the input bar 2 and hence to the specimen 3 when the front end 6a of the projectile interfaces with the end 2a of the input bar. In the example shown, the input and output bars 2,4 are a cylindrical section of similar section to that of the projectile 6.

As previously mentioned in this specification there is an interface problem in the described arrangement between the forward surface 6a of the projectile and impacted surface 2a of the input bar which can give rise to significant difficulties. In order to minimise interface problems the projectile and bar should be perfectly parallel at impact and the guidance surfaces inside the gun need to be smooth and the surfaces 6a and 2a need to be smooth and mechanically treated so that substantially the whole of the surface 6a will contact the whole of the surface 2a at impact.

FIGURE 2 shows, in accordance with the present invention, compression wave generation apparatus 101 to the left of a split Hopkinson pressure bar 102. The split Hopkinson pressure bar comprises an input bar 103 connected via specimen 104, (to be tested in compression) to an output bar 105. The large arrows 106 and 107 represent the direction of a compression wave generated throughout the Hopkinson bar 102. The compression wave generation apparatus 101 has a hydraulic actuator 108 (the form of actuator could be any convenient means for example pneumatic rather than hydraulic operation) that in use induces a preload (represented by arrow A) force on an impactor bar or member 109, the right-hand end 109a of which is positioned adjacent the input or impact end 103a of the input bar 103. A fragile or frangible component 110 is provided along the length of the impactor bar 109, said frangible member being arranged to rupture at a particular value of the preload force provided by the actuator. The forward end 109a of the impactor 109 is guided and held adjacent the end 103a of the input bar 103 by means of a cylindrical collar 111 welded to said end 109a of the impactor 109. The internal diameter 111a of the collar 111 closely matches the diameter of the input bar 103

which in turn matches the diameter of the impactor bar 109 in a manner which should be evident from the drawings.

A blocking system or fixed support 112 is provided at the rear of the collar 111 surrounding the impactor bar 109 thereby resisting or preventing movement of the impactor bar 109 to the left of the support 112 on application of the preload force in the direction of arrow "A" by the hydraulic actuator 108. Under a preload force the rear face 111b of the collar 111 is urged tightly against the front face 112a of the blocking system 112 in such a manner that no preload force will be exerted on the input bar 103 in the direction of arrow "A". However, once the preload force reaches a known preset level, the fragile member 110 will rupture and the action force in the impactor bar will cause an impact at the interface between the impact surface 109a of the impactor bar and the input end 103a of the input bar 103 in a manner which should be self-evident. Furthermore, the impact will result in a compressive stress wave of precisely known amplitude and duration to be generated through the input bar 103, the specimen 104 and the output bar 107. Thus, the compression wave generation apparatus relies on the principle of storing elastic potential energy in the preloaded static impactor bar and then suddenly releasing that energy (for example by rupturing of a fragile member in the impactor bar) so that the impactor bar impacts the input bar. Thus, the afore-described invention in relation to FIGURE 2 of the drawings avoids problems with the prior art arrangement discussed in relation to FIGURE 1 owing to the unique continuous bar system 109,103 being divided into an impactor and an impacted system by the welded cylinder blocking system. The contact achieved by the impactor bar 109 and the input or impacted bar is nearly perfect and effectively the pulse generation propagates through the entire system without any noticeable perturbations unlike the arrangement described in relation to FIGURE 1.

In the arrangement as described in relation to FIGURE 1, if the diameter of the input bar is increased in order to test a larger specimen, the diameter of the projectile 6 necessarily needs to be increased so that the gun 5 will need modification or replacement by a gun able to deliver a larger projectile. However, in the arrangement as shown in the present invention in relation to FIGURE 2, a larger diameter specimen can be tested much more easily simply by increasing the diameter of the input and output bars and impactor bar accordingly. The same actuator means 108 can be used.

Furthermore, it is also possible to change relatively easily the geometry of the Hopkinson bar to give, for example, a rectangular or square section of bar where required. In such a circumstance complex modifications would have to be made to a gas gun to send an appropriately sized projectile of similar section into impact with such a bar.

The apparatus in accordance with the present invention could be used for dynamic mechanical characterisation of concrete where three types of test specimen are generally used namely tubes, cylinders and prisms. Cylinders are used as the standard specimen in the United States, Canada and New Zealand whereas cube shapes are generally used in European countries.

It is to be noted that, in the arrangement shown in FIGURE 2, the length of the preloaded bar 109 can be increased up to several meters, in order to increase the length of the compression pulse without problems of vibration or guidance as will be the case with the arrangement shown in FIGURE 1 with a projectile inside a gun. Therefore, the arrangement shown in FIGURE 2 has an additional advantage over the arrangement shown in FIGURE 1 in that the length of the compression pulse can be increased up to several meters without such vibrational problems.

It is to be understood that the scope of the present invention is not to be unduly limited by a particular choice of terminology and that a specific term may be replaced by any equivalent or generic term. Further, it is to be understood that individual features, method or functions relating to the compression wave or pulse generation apparatus might be individually patentably inventive. The singular may include the plural and vice versa. Additionally, any range mentioned herein for any variable or parameter shall be taken to include a disclosure of any derivable subrange within that range or any particular value of the variable or parameter arranged within, or at an end of, the range or subrange.

Further according to the present invention there is provided a method of generating a compression wave in a pressure bar system such as a split Hopkinson pressure bar by utilising the elastic stored energy in a preloaded impactor bar/member by suddenly releasing that stored energy so that the impactor bar/member impacts an input bar.

Further according to the present invention there is provided apparatus for carrying out the above method.

The compression wave or pulse generation apparatus might be capable or adapted to generate a compression wave or pulse in a particular item or equipment (under test) rather than in a pressure bar system and such an arrangement may be patentably inventive.

#### Claims

1. Compression wave or pulse generation apparatus capable of generating a compression wave or pulse in an input bar or member of a pressure bar system such as a split Hopkinson pressure bar, said compression wave generation apparatus comprising an impactor bar or member held, in use, adjacent one end of the input bar or member and supported to resist movement in a direction away from said input bar/member when the impactor bar/member is preloaded in said direction by actuator means, the

arrangement being such that, in use, the pre-load force can be quelled suddenly e.g. by rupture of a fragile or frangible component in the impactor bar/member, so that the impactor bar/member is released into impact or energy transfer with the input bar/member thereby transmitting a compression wave or pulse through the input bar to a specimen under test.

2. Apparatus as claimed in Claim 1 in which the actuator means is hydraulic or pneumatic actuator.
3. Apparatus as claimed in Claim 1 or Claim 2 in which a fragile or frangible component is provided in the impactor bar.
4. Apparatus as claimed in Claim 3 in which the fragile or frangible component is arranged to rupture at a particular pre-set value of the preload force provided by the actuator means.
5. Apparatus as claimed in any one of the preceding claims in which the impactor bar/member is guided and held adjacent an input end of the input bar/member.
6. Apparatus as claimed in Claim 5 in which a collar is connected to one end of said impactor bar/member.
7. Apparatus as claimed in Claim 6 in which the collar receives the input end of the input bar and holds same adjacent the impact end of the impactor bar/member.
8. Apparatus as claimed in Claim 7 in which said collar is welded to the end of the impactor bar/member and/or is cylindrical and/or preferably, the internal diameter or dimension of the collar closely matches the external diameter or dimension of the input bar which in turn matches the diameter or dimension of the impactor bar.
9. Apparatus as claimed in any one of claims 6 to 8 in which a blocking system or fixed support is provided at the rear of the collar surrounding the impactor bar/member thereby resisting or preventing movement of the impactor bar in said direction on the application of the preload force.
10. Apparatus as claimed in any one of the preceding claims in which the input bar is connected to an output bar via the specimen to be placed under a compression test.
11. A method of inducing or generating a compression wave or pulse in an input bar or member of a pressure bar system such as split Hopkinson pressure bar, said method comprising pre-loading an impac-

tor bar or member in a direction away from said input bar and suddenly removing the preload force thereby releasing the impactor bar/member into impact or energy transfer with the impactor bar/member, thus transmitting a compression wave through the input bar to a specimen under test. 5

12. A method as claimed in Claim 11 including suddenly removing the preload force by rupturing a fragile or frangible component of the impactor bar/member. 10

13. A method of generating a compression wave in a pressure bar system such as a split Hopkinson pressure bar by utilising the elastic stored energy in a pre-loaded impactor bar/member by suddenly releasing that stored energy so that the impactor bar/member impacts an input bar. 15

14. Apparatus for carrying out the method as claimed in Claim 13. 20

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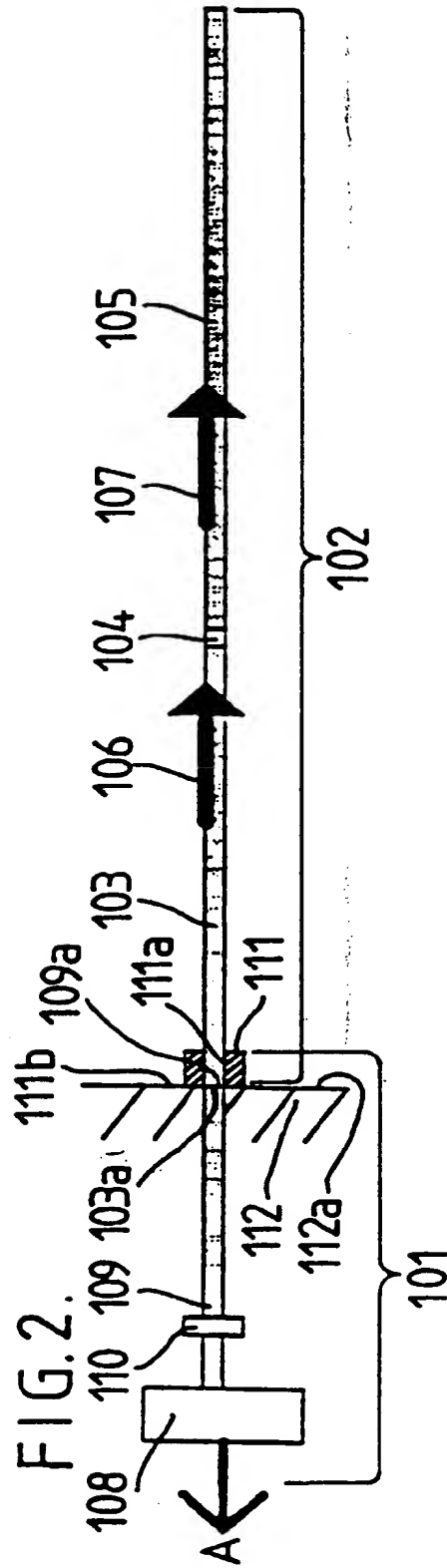
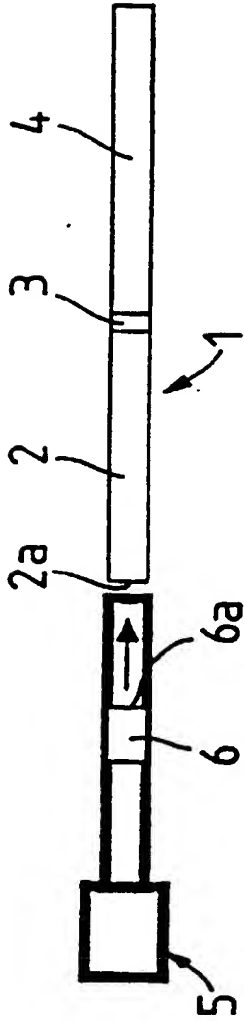
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FIG. 1.





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# EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 9085

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X A	US 4 159 039 A (HIROSE TETSUZO ET AL) 26 June 1979 * column 3, line 21 - column 6, line 33 * * column 11, line 3 - line 42 * * column 12, line 43 - column 13, line 12; figures 1,3,8,13,14 *	1,2,5, 10,13,14 6-9	G01N3/30
X	MEASUREMENT SCIENCE & TECHNOLOGY, JULY 1996, IOP PUBLISHING, UK, vol. 7, no. 7, ISSN 0957-0233, pages 1068-1072, XP000632368 HAMDAN S ET AL: "A crossbow system for high-strain-rate mechanical testing"	13,14	
A	* the whole document *	1-12	
A	EXPERIMENTAL MECHANICS, SEPT. 1991, USA, vol. 31, no. 3, ISSN 0014-4851, pages 232-235, XP000672536 STAAB G H ET AL: "A direct-tension split Hopkinson bar for high strain-rate testing"		TECHNICAL FIELDS SEARCHED (Int.Cl.6)
	* page 232, right-hand column - page 233, left-hand column; figures 1-3 *		G01N
A	EP 0 410 370 A (EUROPEAN COMMUNITIES) 30 January 1991		
A	JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS, vol. 12, 1964, pages 317-335, XP000618916 LINDHOLM U S: "SOME EXPERIMENTS WITH THE SPLIT HOPKINSON PRESSURE BAR"		
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 11 June 1997	Examiner Hodson, M
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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